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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

DEVELOPMENTS IN BUS AND TRUCK LUBRICATION

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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Developments in Bus and Truck Lubrication

INTERESTED in statistics? Here are a few about the bus and truck industry and its relation to the petroleum industry.

At the close of 1948, it was estimated that a total of almost 41,000,000 motor vehicles were operating in the United States. Of this number, buses totaled about 188,000* or only 0.5%. Trucks totaled about 7,500,000** or 18.4%. The remainder were passenger cars.

During 1948 the bus industry* spent a total of $614,000,000 excluding taxes and labor for capital outlay and operating supplies. Of this amount, $125,000,000 or about 20% was spent for gasoline, Diesel fuel, lubricating oil and grease. Appreciating the fact that there are about 40 times as many trucks of all types as there are buses, the combined expenditure of the bus and truck industry for fuels and lubricants really gives the petroleum industry some food for thought.

On the other side of the picture, the bus industry spent $92,000,000 or about 15% for repairs including replacement parts, maintenance materials and supplies but excluding labor. The combined expense for fuels, lubricants and maintenance amounts to approximately 35 cents out of each dollar spent.

THE bus and truck industry has come a long way since the "jitney" age. To the casual observer the outstanding changes have involved appearance, size and dependability as to timetables and delivery. The assembly of machinery under the hood and on the chassis should be of equal interest. Here, too, size has been increased in keeping with the loads to be carried. Most important, however, is the dependability of this assembly of machinery. It is this dependability which has made possible the timetables which are taken so casually today.

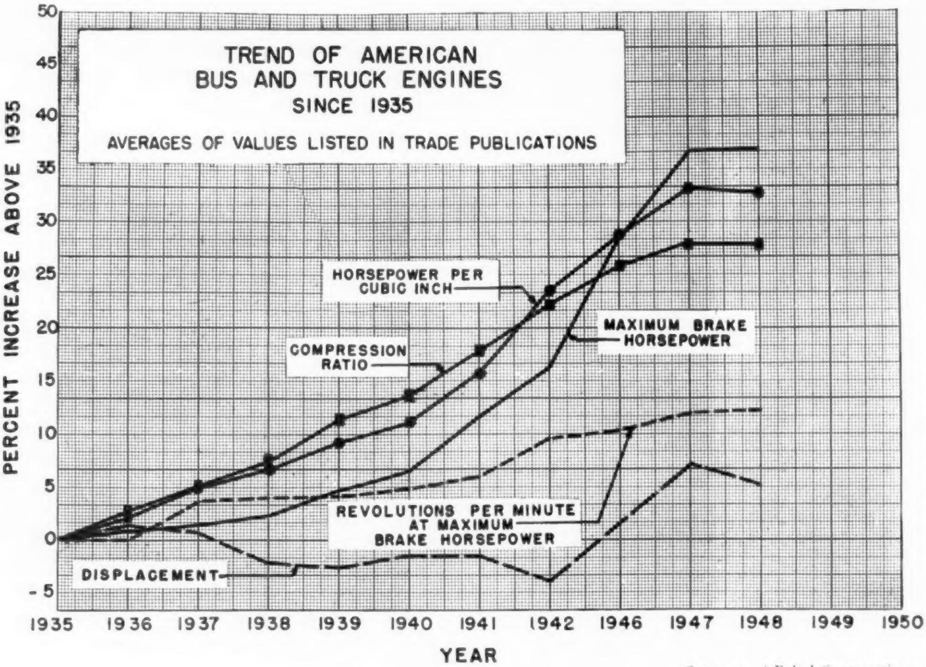
Petroleum quite naturally played a major part in the development of this vast industry. Machinery cannot run without lubrication. Internal combustion engines must have fuel. The technologists of the petroleum industry, therefore, worked with the engineers in the automotive industry and kept pace with the mechanical developments by producing the high quality fuels, gear lubricants, engine oils and chassis and wheel bearing greases which enable the modern bus and truck to operate so continuously and so economically. The dependability of these petroleum products has a definite effect upon the cost per mile of operation.

The question then arises as to what saving in this expensive item could be realized by the use of the improved lubricants developed by the oil industry, in conjunction with better maintenance and lubrication practices. It is the purpose of this article to review some of these lubrication developments which may lead to the attainment of these savings.

ENGINE LUBRICATION

The trend in the design and performance of American bus and truck engines since 1935 is shown in Figure 1. Increases in compression ratio and engine speed have permitted marked increases in power with

*Bus Transportation—February, 1949. **Motor Truck Facts—1949 Edition.



Courtesy of Ethyl Corporation

Figure 1 — Trend of American Bus and Truck Engines since 1935

only a slight increase in engine size in recent years. These important improvements in engine performance have been made possible by commensurate improvements in fuels and in particular, engine oils.

Heavy-Duty Oils

Satisfactory performance of modern heavy-duty commercial gasoline and Diesel engines in bus and truck service requires engine oils having the properties of:

Oxidation Resistance	Anti-Rust
Corrosion Prevention	Extreme Pressure
Detergency	Anti-Wear
Dispersion	Anti-Foam

Engine oils possessing these properties are classified as heavy-duty oils. Among the accepted criteria for a satisfactory heavy-duty oil for automotive gasoline and Diesel engines is U. S. Army Specification 2-104B, which was issued in May 1943. Embroiled in World War II at that time, the U. S. Army's admirable standardization program required for simplication of the supply problem an engine oil which would be suitable for all types of engines in all types of service.

Considerable data were already available on the satisfactory performance of engine oils of the "heavy-duty additive type" in various types of automotive engines in civilian commercial vehicle service. This type of oil was selected by the Army to provide the desired universal applicability. The resultant specification which satisfied minimum service requirements was drawn up around a series of five laboratory engine tests which were being used in the development of heavy-duty oils at that time. Details of these engine tests were discussed in a previous issue of "Lubrication".*

At the present time, the engine test requirements of this specification which covers only the SAE 10, 30 and 50 grades have been reduced to the following two procedures:

Ordnance Dept. Specification	*CRC Designation*	*Engine*	*Title*
AXS-1551	L-1-545	Caterpillar Single-Cyl. Diesel	Test Procedure for Determining in an Engine the Effect of Engine Oils on Ring-Sticking, Wear, and the Accumulation of Deposits.
AXS-1554	L-4-949	Chevrolet 6-Cylinder Gasoline	Test Procedure for Determining Oxidation Characteristics of Heavy-Duty Crankcase Oils.

*"Lubrication"—November, 1943.

Improvements in engine design, more varied operating conditions and changes in fuel characteristics have shown the need for oils with an even higher performance level than presently supplied by 2-104B oils in general. Increasing use of supercharging has again created a deposit problem in the ring zone. The increasing use of high sulfur Diesel fuels has had a pronounced effect on engine deposits and wear.

Super Duty Oils

Appreciating all these factors, and principally the effect of high sulfur fuel, the Caterpillar Tractor Company developed a special supercharged single-cylinder engine test procedure to evaluate oils with improved characteristics. This test is known as the Caterpillar 1-D Supercharged Engine Test and is conducted using a Diesel fuel of high sulfur content (1.0%). Operating conditions of this test procedure are compared with those for the standard CRC L-1 Caterpillar Diesel engine test in Table 1.

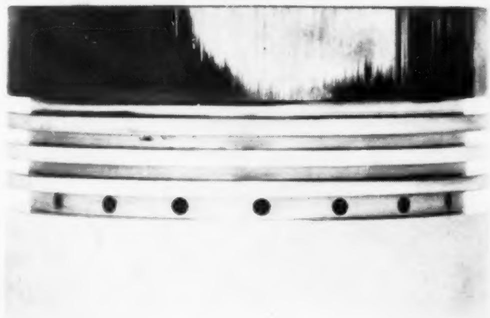
Following the successful completion of a run under 1-D test conditions, the oil is then subjected to a multi-cylinder supercharged Diesel engine test followed by an extensive field test program using high sulfur fuel in both cases. Oils satisfying the requirements of all phases of these tests are then accepted by Caterpillar as "Superior Lubricants (Series 2)."

In the service application of these oils, Caterpillar urges that their customers operating with Diesel fuels having sulfur contents higher than 0.5% take advantage of the benefits provided by Series 2 lubricants. In addition, these oils are recommended by Caterpillar for use in their new series

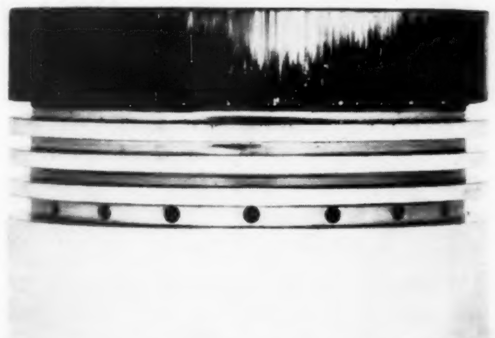
TABLE 1

Comparison of Operating Conditions Caterpillar Single-Cylinder Diesel Test Engines

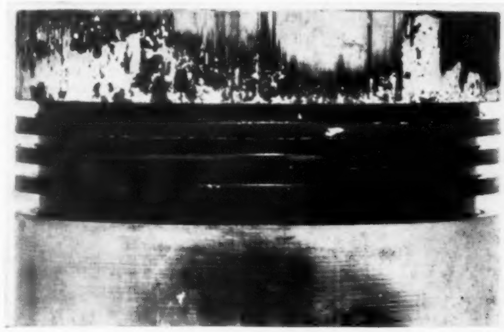
Procedure	*L-1*	*1-D*
Test period, hrs.	480	480
Oil change period, hrs.	120	120
Engine speed, rpm	1000	1200
Jacket outlet, °F.	175	200
Oil to bearings, °F.	145	175
Exhaust back pressure	less than 1 "Hg.	less than 1 "Hg.
BTU. input, avg./minute	2950	5600
BHP	19.8	42
Air intake temperature, °F.	room	200
Air intake pressure, "Hg.	0	15
Sulfur content of fuel, %	0.4 max.	0.95—1.05



Series 2 Oil



Supplement 1 Oil



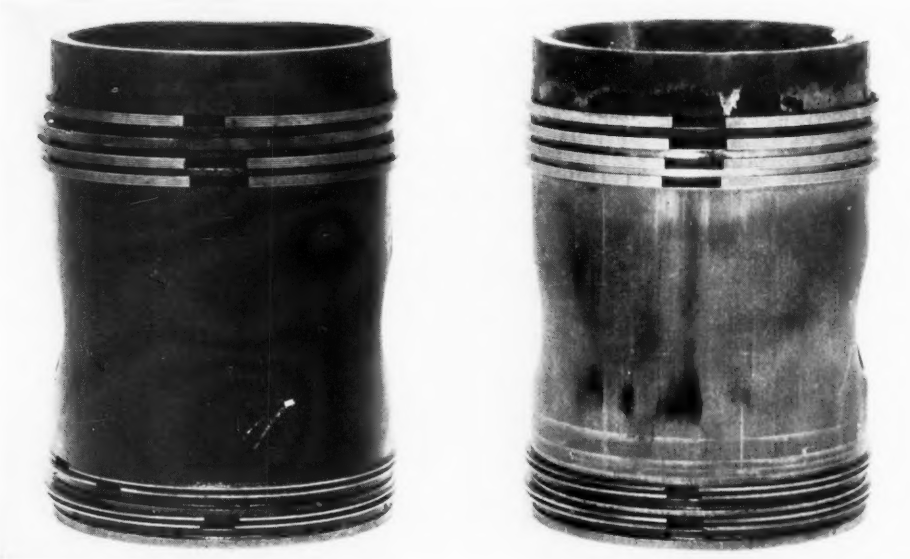
Courtesy of Lubrizol Corporation

2 — 104B Oil

Figure 2 — Comparison of ring-zone cleanliness. CRC L-1 Caterpillar Diesel engine test procedure modified with use of high sulfur (1.0%) fuel.

of supercharged Diesel engines regardless of the sulfur content of the fuel.

Products developed to satisfy these requirements have achieved a performance level in Diesel engine lubrication far superior to that provided by the average 2-104B type oil. See figures 2 and 3. Of necessity, however, these new oils generally termed



2 – 104B Oil   Series 2 Oil

Courtesy of Lubrizol Corporation

Figure 3 – Comparison of piston cleanliness. Modified GM 71 Diesel engine test procedure using high sulfur (1.0%) fuel.

"super duty oils" as contrasted to heavy-duty oils, contain much higher concentrations of additives which naturally increased their cost. Consequently, their use is largely confined to Diesel engines where difficulties have been encountered with high sulfur fuel. Some data have been obtained, however, on the performance of this type oil in gasoline engines in commercial vehicle service. Figure 4 shows comparative piston conditions after 6,000 miles in heavy-duty truck service over mountainous terrain. Results also indicate that the high degree of detergency of super duty oils makes them particularly suitable for delivery vehicle service involving low engine operating temperatures.

Intermediate Duty Oils

The extremely wide spread between the performance levels of super duty oils and heavy-duty oils has suggested that some compromise oil could be developed which would provide the required improvement but with more economical additive treating costs. The need for this development has been recognized principally by the U. S. Army Ordnance Department when requirements for Supplemental Lists 1 and 2 under U. S. Army Specification 2-104B were established in May, 1949.

Oils acceptable for qualification under Supplemental List 1 must satisfy all requirements of the regular 2-104B tests and, in addition, must pass an L-1 Caterpillar single-cylinder Diesel engine test using a fuel with 1% sulfur content. Products satisfying these requirements provide greatly improved performance over 2-104B oils at less cost than the Caterpillar Series 2 oils as shown by the comparison in Figure 2.

Untreated Base Oil   2 – 104B Oil   Series 2 Oil

Courtesy of Lubrizol Corporation

Figure 4 – Comparison of piston cleanliness. Gasoline engine in heavy-duty truck after 6,000 miles over mountainous terrain.

Oils acceptable for qualification under Supplemental List 2 are those which in addition to meeting all the requirements of 2-104B, Supplemental List 1, also meet the additional and more severe requirements of Caterpillar Superior Lubricants Series 2. While the issuance of these Supplemental Lists to 2-104B by the Ordnance Department recognizes the development of oils of these types, specific recommendations on their service use still remain to be formulated. Very recently, however, the Ordnance Department has announced its intention to establish a new specification for heavy-duty engine oils which will have a more severe engine test requirement than the present 2-104B specification. With this new level of quality the present Supplemental List 1 will be eliminated as well as the present list of qualified 2-104B oils. A new list of approved oils under the new specification will take their place.

Development of these superior heavy-duty oils has enabled the petroleum industry to keep pace with the bus and truck industry by continuing to supply products which will satisfy the lubrication requirements of new designs, higher speeds, heavier loads and more varied operating conditions.

TRANSMISSION LUBRICATION

One of the greatest developments in the history of automotive transmissions is the transmitting and/or multiplication of engine torque through a fluid medium.[1] Application of this principle is found largely in passenger car transmissions at present, although its use is being extended more and more to buses operating in city service.

Hydraulic Transmissions

Hydraulic transmissions in buses may be classified roughly as follows:

1. Three-stage torque converters combined with one or two automatically controlled clutches.[2] This application is used by such manufacturers as GMC Truck & Coach, Twin Coach, Mack and ACF-Brill.

2. Combination single-stage torque converter and fluid coupling with an automatic two-speed synchromesh transmission.[3] Known as the White Hydro-Torque Drive, it is used exclusively in White transit-type buses.

3. Fluid coupling combined with an automatically controlled four-speed planetary transmission.[4] This is the well-known General Motors passenger car Hydra-Matic transmission which has been applied very recently to the new GM 27-passenger bus.

Table 2 has been prepared showing the various types of hydraulic transmissions or torque converters currently used in transit bus service and the types of hydraulic fluids and lubricants specified by the different manufacturers. The new GM "V" Drive hydraulic transmission is of particular interest in that the same fluid circulating through the torque converter is also used to lubricate the reverse gear train and the angle drive gears. This design eliminates the troublesome seals used previously to prevent leakage of the torque converter fluid into the gear section of the transmission.

Present experience indicates that a heavy-duty 2-104B type engine oil SAE 50 is the most satisfactory lubricant for the separately lubricated angle drive or gear box sections of these hydraulic transmissions.

Conventional Transmissions

Conventional or straight mechanical transmissions still remain in general use for truck service although several truck manufacturers have been experimenting with some type of hydraulic or automatic transmission in light duty delivery type vehicles. Transmissions of the conventional type also continue to be used in inter-city buses where sustained high speed operation predominates.

While most manufacturers still specify a highly refined straight mineral type gear lubricant, there is an increasing trend toward the use of SAE 50 engine oils, particularly of the heavy-duty 2-104B type. Field experience reveals that the good oxidation resistance and anti-corrosive and anti-rust properties of these oils make them ideally suited for lubrication of mechanical transmissions.

The fact that transmission gear cases must be drained periodically, the same as an engine crankcase, is not appreciated sufficiently. Although the intervals between drains as specified by most manufacturers is appreciably longer than for the engine crankcase, the reasons for changing the gear lubricant are essentially the same as those for the engine oil. High lubricant temperature levels prevail which promote oxidation. Contamination with moisture from condensation and rainy weather operation, road dirt and dust, and tiny metal particles occurs. All of these conditions place a burden on the lubricant requiring periodic changes to insure proper lubrication.

REAR AXLE LUBRICATION

Spiral bevel type rear axles continue to be used but hypoid axles in one form or another are becoming more prominent. As a consequence the "all-purpose" or "multi-purpose" type of gear lubricant typified by the requirements of U. S. Army Specification 2-105B is being employed generally for rear axle lubrication of buses and trucks.

[1] Lubrication — November, 1946.
[2] Lubrication — November, 1947.
[3] Lubrication — November, 1948.
[4] Lubrication — April, 1947.

TABLE 2

HYDRAULIC TRANSMISSIONS IN CITY BUSES

Name of Unit	*Description*	*Hydraulic Transmission Fluid*	*Angle-Drive or Gear Box Lubricant*
GM Models 90 & 91 Hydraulic Transmission	Three-stage torque converter, double-acting automatic clutch, reverse gear train and angle-drive bevel gears.	Torque Fluid	Aviation Grade or Heavy-Duty 2-104B Type Engine Oil SAE 50
GM "V" Drive Hydraulic Transmission	Three-stage torque converter, double-acting automatic clutch, reverse gear train and angle-drive bevel gears.	Torque Fluid	Torque Fluid
Mack Hydraulic Torque Converter	Three-stage torque converter, automatic single-clutch, reverse gear train and angle-drive bevel gears.	Torque Fluid	Regular or Premium Type Engine Oil SAE 50
Twin Coach Torque Converter Transmission	Three-stage torque converter, automatic single-clutch and differential reverse gear.	Torque Fluid	Straight Mineral or Oxidation Inhibited Engine Oil SAE 50
ACF-Brill Models 916 & 918 Torque Converter	Three-stage torque converter, automatic single-clutch and differential reverse gear.	Torque Fluid	Straight Mineral Gear Oil SAE 90 or Engine Oil SAE 50
White Hydro-Torque Drive	Combination single-stage torque converter and fluid coupling with automatic two-speed synchro-mesh transmission.	Heavy-Duty 2-104B Type Engine Oil SUMMER—SAE 20* WINTER—SAE 10	Heavy-Duty 2-104B Type Engine Oil SUMMER—SAE 20* WINTER—SAE 10
GM Coach Hydra-Matic Transmission	Fluid coupling and automatic four-speed planetary transmission with angle-drive bevel gears.	GM Automatic Transmission Fluid, Type A	Aviation Grade or Heavy-Duty 2-104B Type Engine Oil SAE 50

*Used throughout the year in most cases.

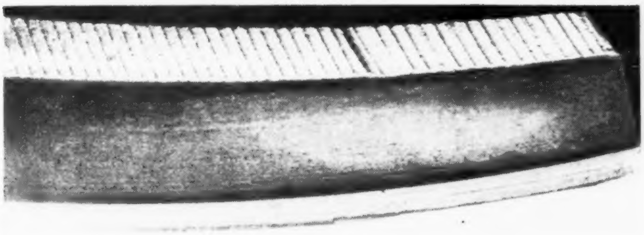


Figure 5 — New ring gear tooth surface — High Speed Axle Test.

Figure 6 — Failed ring gear tooth surface — High Speed Axle Test.

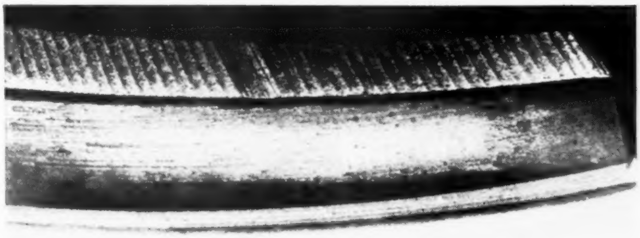


Figure 7 — Satisfactory ring gear tooth surface — High Speed Axle Test.

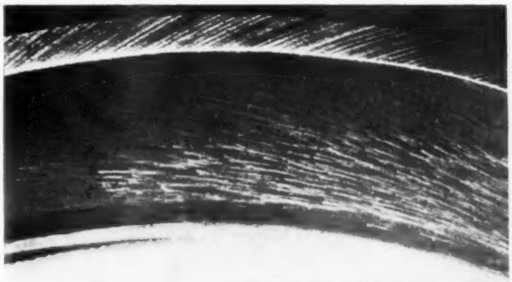


Figure 8 — New pinion gear tooth surface — High Torque-Low Speed Axle Test.

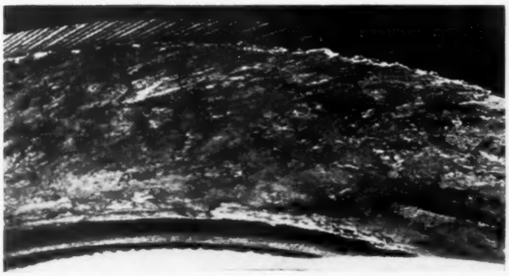


Figure 9 — Failed pinion gear tooth surface due to welding after 3 mins. under load with straight mineral gear lubricant. High Torque — Low Speed Axle Test.

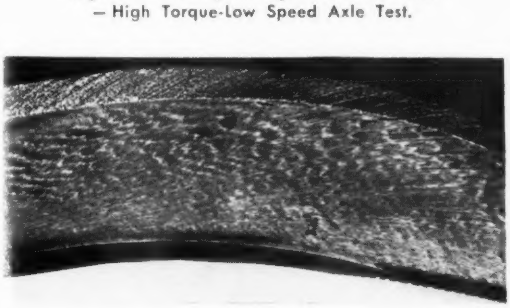


Figure 10 — Failed pinion gear tooth surface due to rippling — High Torque-Low Speed Axle Test.

Courtesy of Lubrizol Corporation

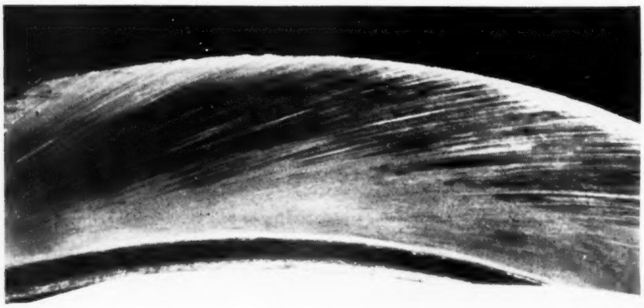


Figure 11 — Failed pinion gear tooth surface due to wear — High Torque-Low Speed Axle Test.

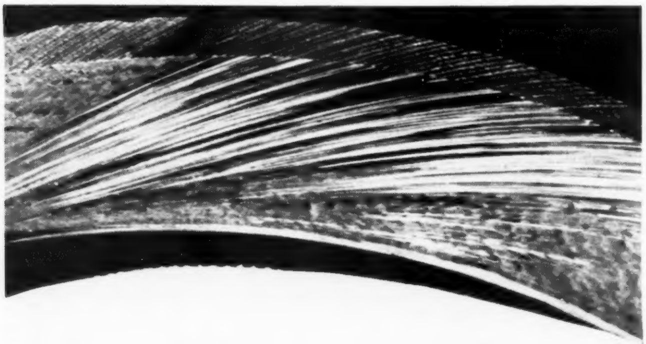


Figure 12 — Failed pinion gear tooth surface due to ridging — High Torque-Low Speed Axle Test.

Figure 13 — Satisfactory pinion gear tooth surface. Dark, irregular lines are original tool marks. High Torque-Low Speed Axle Test.

Courtesy of Lubrizol Corporation

All-Purpose Gear Lubricant Requirements

Gear lubricants of this type must provide satisfactory lubrication for the high-speed, low-torque service conditions of passenger cars and inter-city vehicles and the high-torque, low-speed service conditions of heavy-duty commercial equipment.

As a result of cooperative effort by the automotive manufacturers and the oil industry, a specification was written for the U. S. Army Ordnance Department which was designated as U. S. A. Specification 2-105B, "Lubricant, Gear, Universal."

The principal requirements of this specification which covers three grades are shown in Table 3. Basically, this specification is founded on full-scale axle performance tests with no attempt to control chemical composition. The three axle tests listed are used to indicate the relative performance characteristics of a gear lubricant under conditions of high speed, heavy load and moisture contamination.

TABLE 3

U. S. Army Specification 2-105B
Universal Gear Lubricant
Detail Requirements

	Grade 75	*Grade 80*	*Grade 90*
Flash Point, °F, min.	300	325	325
Viscosity, SUS @ 100°F.	150-190	—	—
Viscosity, SUS @ 210°F.	—	55-65	80-90
Viscosity Index, min.	85	85	85
Channel Point, °F., max.	—50	—30	0
Copper Strip Activity	pass	pass	pass
Rust Protection	pass	pass	pass

Additional Qualification Requirements
Grade 90 Only

U. S. Army Tentative Spec. AXS-1569 High Speed Axle Test

U. S. Army Tentative Spec. AXS-1570 High Torque Axle Test

U. S. Army Tentative Spec. AXS-1571 Moisture Corrosion Axle Test

U. S. Army Tentative Spec. AXS-1572 Storage Solubility Test

U. S. Army Tentative Spec. AXS-1562 . . . . Foaming Test

High Speed Axle Test

Tooth surface condition of a typical new ring gear as used in the High Speed Axle Test is shown in Fig. 5. Tooth surface conditions of unsatisfactory and satisfactory gear lubricants are shown in Figs. 6 and 7 respectively. Note for the unsatisfactory lubricant, the contact area covers a considerable portion of the tooth surface and scoring is evident.

High Torque—Low Speed Axle Test

Under conditions of high torque and low speed typical pinion gear teeth surfaces are shown in Figures 8, 9, 10, 11, 12, and 13. Note the severe welding that has occurred after only three minutes of loaded operation with a straight mineral type lubricant. The satisfactory condition of the gear tooth surface in Figure 13 is indicated by the dark scattered lines which are tool marks as evidenced from a comparison with the new gear tooth surface shown in Figure 8.

Road Tests

Actual service evaluations of gear lubricants are made by conducting road tests under high speed-low torque and high torque-low speed conditions. For the high speed-low torque testing, a late model passenger car is used with a new hypoid rear axle for each run of 664 miles at an average speed of 60 mph. Typical condition of the drive side of the pinion gear teeth for a satisfactory gear lubricant is shown in Figure 14.

For high torque-low speed testing, $1\frac{1}{2}$ ton tractor-trailers are used. The trailers are loaded with concrete blocks to obtain a gross vehicle weight of 24,000 lbs. A new hypoid rear axle is used for

Figure 14 — Satisfactory pinion gear tooth surface — High Speed Road Test.

Figure 15 — Satisfactory pinion gear tooth surface — High Torque Low-Speed Road Test.

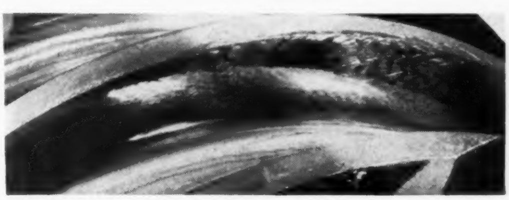
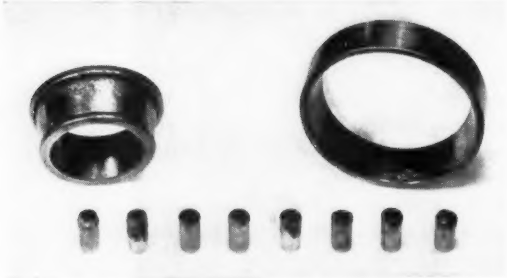


Figure 16 — Failed pinion gear tooth surface due to fish scaling — High Torque-Low Speed Road Test.



Courtesy of Anti-Friction Bearing Manufacturers Assoc., Inc.

Figure 17 — Spalled cone, cup and rollers of tapered roller wheel bearing.

Figure 19 — Rollers of bearing etched by moisture.

Courtesy of Anti-Friction Bearing Manufacturers Assoc., Inc.

Figure 18 — Tapered roller wheel bearing cone etched by moisture.

Figure 20 — Outer surface of wheel bearing cup showing poor contact.

each run of 3000 miles at an average speed of 19 mph over mountainous terrain which requires considerable use of the lower transmission gears. Under these severe operating conditions, a satisfactory gear lubricant provides a pinion gear tooth condition shown in Figure 15. An unsatisfactory gear lubricant may cause the fish scaling condition shown in Figure 16.

WHEEL BEARING LUBRICATION

A great deal of time, money and effort has been spent in the development of special greases for the lubrication of wheel bearings in automotive vehicles operating in heavy-duty service. All of this goes for naught, however, if proper attention is not paid to the application of the lubricant, installation and adjustment of the bearing and its periodic inspection and re-lubrication.

Cleaning and Inspection

In connection with the lubrication and maintenance of wheel bearings, careful attention should be given to the following points:

After removal of the wheel and the bearings, all of the used grease should be washed from both the wheel hub and the bearings. Kerosene or other suitable solvent for automotive parts cleaning should be used. Removal of grease from the bearings may be accomplished best in a spray booth or with a brush. The bearing should be blown dry with moisture-free air and then inspected. Precautions should be taken never to allow a bearing to remain overnight or for any period of time without applying a protective coating of grease or oil to prevent rusting.

Careful inspection of each component of the bearing is an important part of each lubricant repacking period. The following conditions should be checked:

a. Spalling or flaking of races and rollers. This condition is a sign of fatigue failure and usually occurs first on the inner races. Figure 17 shows a spalled cone, cup and rollers of a tapered roller bearing. Spalled bearings of any kind should never be returned to service. The entire bearing should

Figure 21 — A small amount of wheel bearing grease on the fingers of one hand preparatory to packing the bearing cone.

Figure 22 — The bearing, big end up, after it has been placed in the palm of the hand holding the grease. The fingers are working the grease into the cage between the rollers.

Figure 23 — The grease protruding from between the rollers at the small end of the cage following the packing of this portion of the bearing. Working with a small amount of grease prevents obscuring the small end of the cage and permits ready observation of the grease when it begins to protrude between the rollers.

Figure 24 — The grease protruding from between all rollers at the completion of packing the cage.

Figure 25 — A layer of grease being applied around the rollers, filling the spaces between the rollers and completely covering them. This is the final step in the packing of the cone.

Figure 26 — The cone properly packed and ready for installation.

be replaced rather than trying to use a new cone in an old cup and vice versa.

b. Rusting which manifests itself by an etched appearance of the rollers and inner race and is caused by water entry. See Figures 18 and 19. Attention to the condition of grease seals and repacking bearings immediately after extended periods of water contact are necessary precautions to prevent this harmful condition.

c. Excessive cage wear. This condition can be detected by inspection although many experienced operators ascertain cage wear by shaking the cone and noting the extent of rattle as compared with a new bearing cone. In extreme cases of cage wear, the rollers will fall out of the cage.

d. Looseness or misalignment of the cup in the wheel hub. This condition may be observed by the appearance of the outside of the cup. Figure 20 shows the outer surface of a cup which was in contact with its hub recess for only about 50% of its width. A feeler gauge should be used to be sure that the cup is seating firmly and uniformly against the shoulder in the wheel hub.

e. Condition of grease seals. These should be inspected carefully for wear of the sealing material in contact with the axle shaft. Poor fit of the seal in the hub is often responsible for this wear. Seals should be replaced if there is any question as to their suitability for further service.

Lubrication

Lubrication of the bearing cone may be accomplished by employing a good mechanical bearing packer or by packing manually. Regardless of which method is employed, cleanliness is extremely important. Not only should the bearings and bearing packer be kept clean but the hands of the person handling them should be thoroughly washed *before* the inspection and lubrication procedures.

Although lubrication of the bearing with a good mechanical packer is preferred, many operators still pack wheel bearings by hand. There is considerable doubt, however, that the proper method of hand-packing a wheel bearing is generally understood. While it appears simple, a certain knack is required and Figures 21 through 26 have been prepared to show the successive steps in hand-packing a wheel bearing. Note that the hands *are clean.*

The necessity for placing wheel bearing grease in the wheel hub is a matter of considerable controversy due to the dangers of over-packing. One bus and truck manufacturer specifies that the rear wheel hub cavity should be packed "to the level of the inside circumference of the bearing cups" and for the front wheel hub, "fill end cavity ⅔ full." Others specify lesser quantities in the wheel hubs. In any event it appears desirable to place some grease in the hub cavities to prevent rusting and to aid in preventing excessive loss of grease from the bearings into the hubs. Particular care must be taken, however, to insure that wheel hubs are not filled completely. Over-filling is undesirable and may be dangerous because the expansion resulting from the temperature rise during operation creates a pressure which can force the grease past the seals and onto the brake lining.

SUMMATION

These important developments in lubricants and lubrication for buses and trucks did not come overnight. Their quality, dependability and outstanding performance characteristics were produced only after extensive research, careful laboratory testing and long periods of service operation under a variety of conditions. All of this work would have gone for naught without the interest and cooperation of the automotive industry and the bus and truck operators.

It is one thing to make a good product but it is another thing to have it perform satisfactorily in service. As the immortal Robert Burns phrased it — "The best laid schemes o' mice and men gang aft agley." So it is that maintenance — properly understood and accurately and painstakingly applied at regularly scheduled intervals — can provide the means to attain the ultimate goal of satisfactory, economical performance and long vehicle life.

The summation of this discussion may be found in the well-known and aptly phrased statement — "The right lubricant in the right amount at the right place at the right time."

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